



Group # : \_\_\_\_\_

Date: 11/26/24

Rating: \_\_\_\_\_

Members			

## **Experiment #6: Final Project**

### **I. Learning Outcomes:**

*At the end of this laboratory experiment, the students should be able to:*

- a) Develop a system simulating the operations of memory, CPU, and ISA.

### **II. Materials:**

PC/Laptop  
Internet

IDE

### **III. Overview:**

#### **Fetch-Decode-Execute cycle**

This cycle describes the basic steps that a CPU follows to execute instructions.

**Fetch:** The CPU retrieves (fetches) the next instruction from the memory. The address of the instruction to be fetched is stored in the program counter (PC).

**Decode:** The fetched instruction is decoded to determine what operation needs to be performed. This involves interpreting the opcode (operation code) of the instruction.

**Execute:** The CPU performs the operation specified by the decoded instruction. This could involve arithmetic or logic operations, data transfers, or control operations.

After the execution, the cycle repeats with the program counter being updated to point to the next instruction in memory.

It's important to note that this cycle is the basic building block of the CPU's operation, and it is repeated for each instruction in a program. The specific details of each step can vary depending on the architecture of the CPU.

In this laboratory, students are going to create a software simulator that would show the inner workings of computers with the involvement of ISA, memory, and CPU.

#### IV. Project Requirements:

- ✓ Simulator w/ GUI
- ✓ System can be built using any programming language, stack, or framework
- ✓ Documentation should contain the following:
  - Overview: Description/ Features/Purpose
  - Discussion of features supported by images
  - Discussion of IMPORTANT code supported by code snippets
  - Conceptual, Use Case, and Class Diagram
  - Answer to the Test Cases
- ✓ There will be a live demonstration of the system
- ✓ Criteria
  - Documentation = 30%
  - Code = 20%
  - System = 50%

**NOTE:** You can add features and enhance the GUI by adding animations. Here is the link to the video where this project was inspired [How does a computer run a program? eChalk instructional video - YouTube.](#)

#### Problem Overview

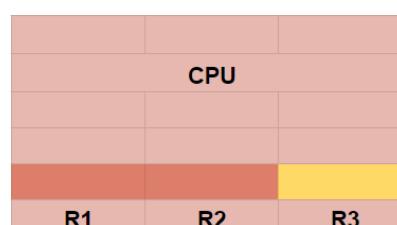
The project will simulate how a computer system executes instructions having three main parts: CPU, Memory, and the Instruction Set.

#### Sample UI:

CPU			MEMORY	HISTORY
R1	R2	R3	A1 5 A2 2 A3 A4 A5 A6 A7 A8 A9 A10	
INSTRUCTIONS				
LOAD			STORE	
from:	to:		from:	to:
A1	R1		R3	A7
ADD R1,R2->R3			SUB R1,R2->R3	

#### CPU:

The CPU should have 3 registers (R1, R2, and R3). Users should not be able to input anything on the registers. It should only be displaying values as per instruction.



#### Memory:

The memory should have 10 addresses (A1 to A10). Users should be able to input values.

MEMORY	
A1	5
A2	2
A3	
A4	
A5	
A6	
A7	
A8	
A9	
A10	

### Instruction Set:

This is where all the functionalities should be initiated. There should be 4 buttons (the green ones). Each button has its own functionality. For the load() function, it should be able to transfer data stored in the memory (A1-A10) to the registers (R1-R3). Also, after transferring the value, the address where the latter was stored should be emptied. For the store() function, it should transfer value stored in the register to memory. For the add() function, it should add data stored in R1 & R2 and store it in R3. Lastly, for the sub() function, it should subtract data stored in R1 & R2 (R1-R2) and store it in R3. A history should also be added to record the operations.

INSTRUCTIONS	
<b>LOAD</b>	
from:	to:
A1	R1
<b>STORE</b>	
from:	to:
R3	A7
<b>ADD R1,R2-&gt;R3</b>	
<b>SUB R1,R2-&gt;R3</b>	

# Computer Organization and Architecture Laboratory

## FINAL PROJECT DOCUMENTATION

### Overview

The CPU Simulator is an innovative application developed using Flutter and Dart, designed to create an engaging and interactive visualization of CPU operations, memory management, and fundamental concepts of instruction set architecture (ISA). This application boasts a modern and animated user interface, enhanced by a visually appealing gradient background that contributes to a responsive design, ensuring a seamless experience across various devices.

### Purpose

The primary purpose of the CPU Simulator is to illustrate core concepts of computer architecture through an interactive graphical user interface (GUI). It enables users to visualize the data flow between CPU registers and memory, offering a clearer understanding of how these components interact during processing tasks. Additionally, the simulator provides hands-on experience with basic CPU operations, allowing users to engage directly with the mechanisms that drive computing. A key feature of the application is its ability to log and display operation history in real-time, which not only enriches the learning experience but also allows users to track the performance and behavior of the CPU as they experiment with different operations.

### Developed User Interface (UI)



### Key Features

- Responsive Flutter UI with adaptive layout for different screen sizes
- Beautiful gradient background and animated components
- Three CPU registers (R1, R2, R3) with real-time value display
- Ten memory addresses (A1-A10) with user input capability
- Basic instruction set (LOAD, STORE, ADD, SUB)
- Comprehensive operation history logging
- Animated transitions and interactions
- Reset functionality

## Features Discussion

### 1. CPU Module

The CPU module features three interactive registers (R1, R2, R3) with:

- Gradient-styled containers for visual appeal
- Click selection functionality
- Real-time value updates
- Visual feedback for selected registers

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### 2. Memory Module

The memory module provides:

- Ten addressable locations (A1-A10)
- Interactive text input fields
- Visual selection feedback
- Clear value display
- Input validation for numeric values

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### 3. Instruction Set Module

Features four core operations with animated buttons and dropdown selectors:

- LOAD: Transfers data from memory to registers
- STORE: Transfers data from registers to memory
- ADD: Performs addition ( $R1 + R2 \rightarrow R3$ )
- SUB: Performs subtraction ( $R1 - R2 \rightarrow R3$ )

Features four core operations with animated buttons and dropdown selectors:

LOAD: Transfers data from memory to registers

STORE: Transfers data from registers to memory

ADD: Performs addition ( $R1 + R2 \rightarrow R3$ )

SUB: Performs subtraction ( $R1 - R2 \rightarrow R3$ )

## Important Code Snippets

The CPU Simulator was developed using Flutter and Dart, with Visual Studio Code as the primary development environment. Below, you'll find key code snippets that were instrumental in the creation of the system.

- **Main Widget Structure**

```
6  class CPUSimulator extends StatefulWidget {
7    const CPUSimulator({super.key});
8
9    @override
10   State<CPUSimulator> createState() => _CPUSimulatorState();
11 }
12
13 class _CPUSimulatorState extends State<CPUSimulator>
14   with TickerProviderStateMixin {
15   final List<int> registers = List.filled(3, 0);
16   final List<TextEditingController> memoryControllers =
17     List.generate(10, (index) => TextEditingController());
18   final List<String> history = [];
19   final ScrollController _scrollController = ScrollController();
```

This code defines the core data structures of the CPU Simulator:

- Creates three CPU registers (R1, R2, R3) to store computational values
- Establishes 10 memory locations (A1-A10) for data storage
- Implements an operation history list to track and display performed actions
- Uses state management to dynamically update and track changes in the simulator

- **Instruction Operations Implementation**

```
57 void load() {
58   if (selectedFromMemory != null && selectedToRegister != null) {
59     setState(() {
60       int memoryIndex = int.parse(selectedFromMemory!.substring(1)) - 1;
61       int registerIndex = int.parse(selectedToRegister!.substring(1)) - 1;
62       int value = int.tryParse(memoryControllers[memoryIndex].text) ?? 0;
63       registers[registerIndex] = value;
64       memoryControllers[memoryIndex].clear();
65       _addToHistory(
66         "Load: $selectedFromMemory($value) → $selectedToRegister(${registers[registerIndex]})");
67     });
68   }
69 }
70
71 void store() {
72   if (selectedFromRegister != null && selectedToMemory != null) {
73     setState(() {
74       int registerIndex = int.parse(selectedFromRegister!.substring(1)) - 1;
75       int memoryIndex = int.parse(selectedToMemory!.substring(1)) - 1;
76       int value = registers[registerIndex];
77       memoryControllers[memoryIndex].text = value.toString();
78       _addToHistory(
79         "Store: ${selectedFromRegister}($value) → ${selectedToMemory}($value)");
80     });
81   }
82 }
83
84 void add() {
85   setState(() {
86     int r1Value = registers[0];
87     int r2Value = registers[1];
88     registers[2] = r1Value + r2Value;
89     _addToHistory(
90       "Add: R1 + R2 → ($r1Value) + ($r2Value) → R3(${registers[2]})");
91   });
92 }
93
94 void subtract() {
95   setState(() {
96     int r1Value = registers[0];
97     int r2Value = registers[1];
98     registers[2] = r1Value - r2Value;
99     _addToHistory(
100       "Sub: R1 - R2 → ($r1Value) - ($r2Value) → R3(${registers[2]})");
101   });
102 }
```

#### LOAD Operation:

- Transfers data from a selected memory address to a specified register
- Checks for valid memory and register selections
- Clears the source memory address after transfer
- Updates the operation history with transfer details

#### STORE Operation:

- Transfers data from a selected register to a specified memory address
- Validates that the register contains a valid numeric value
- Checks for appropriate memory location selection
- Updates the target memory address with the register's value
- Logs the store operation in the history with relevant details

#### ADD Operation:

- Performs arithmetic addition of values stored in R1 and R2
- Stores the result in R3 register
- Validates that R1 and R2 contain numeric values
- Adds the operation to the history log with timestamp and calculation details

#### SUB Operation:

- Performs subtraction by subtracting the value in R2 from R1 ( $R1 - R2$ )
- Stores the result in the R3 register
- Validates that R1 and R2 contain numeric values
- Handles potential negative result scenarios
- Adds the subtraction operation to the history log with calculation specifics

- ***Responsive Layout Implementation***

```
152    @override
153    Widget build(BuildContext context) {
154        return Scaffold(
155            body: Container(
156                decoration: BoxDecoration(
157                    gradient: LinearGradient(
158                        begin: Alignment.topLeft,
159                        end: Alignment.bottomRight,
160                        colors: [
161                            Colors.pink.shade50,
162                            Colors.purple.shade50,
163                            Colors.blue.shade50,
164                        ],
165                    ), // LinearGradient
166                ), // BoxDecoration
167                child: Padding(
168                    padding: const EdgeInsets.all(16.0),
169                    child: Column(
170                        children: [
171                            // Header
172                            Row(
173                                mainAxisAlignment: MainAxisAlignment.spaceBetween,
174                                children: [
175                                    Text(  
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```

```

156     "◆ Your Virtual CPU Workspace ◆",
157     style: GoogleFonts.poppins(
158         color: Colors.pink.shade700,
159         fontWeight: FontWeight.bold,
160         fontSize: 24, // Adjust the size as needed
161     ),
162     ).animate().fadeIn(duration: 600.ms).scale(delay: 300.ms), // Text
163     IconButton(
164     onPressed: reset,
165     icon: Icon(Icons.refresh_rounded,
166         color: Colors.pink.shade400), // Icon
167     tooltip: "Reset All",
168     ).animate().fadeIn(duration: 600.ms).scale(delay: 300.ms), // IconButton
169     ],
170 ), // Row
171 const SizedBox(height: 16),
172 // Main Content
173 Expanded(
174     child: LayoutBuilder(
175         builder: (context, constraints) {
176             return constraints.maxWidth > 1200
177                 ? _buildWideLayout()
178                 : _buildNarrowLayout();

```

- Implements a responsive user interface that adapts to different screen sizes
- Uses LayoutBuilder to create dynamic layouts
- Arranges CPU registers, memory, and instruction set components flexibly
- Ensures consistent UI experience across various device screen dimensions
- Utilizes column and row widgets for structured, adaptive positioning
- Implements padding and spacing for clean, readable interface design

- ***Animation Implementation***

```

27     late AnimationController _animationController;
28     late Animation<double> _scaleAnimation;
29
30     @override
31     void initState() {
32         super.initState();
33         _animationController = AnimationController(
34             duration: const Duration(milliseconds: 300),
35             vsync: this,
36         ); // AnimationController
37         _scaleAnimation = Tween<double>(begin: 1.0, end: 1.1).animate(
38             CurvedAnimation(parent: _animationController, curve: Curves.easeInOut),
39         );
40     }

```

- Integrates smooth animations using flutter\_animate package
- Adds visual feedback and interactivity to UI components
- Implements fade, scale, and slide animations for buttons and history list
- Creates engaging transitions between different states of the simulator
- Enhances user experience through subtle, meaningful animated interactions

## Implementation Details

*Flutter packages used in the application:*

- flutter\_animate for smooth animations
- google\_fonts for typography
- Built-in Flutter animation controllers for custom animations

*Key UI Components:*

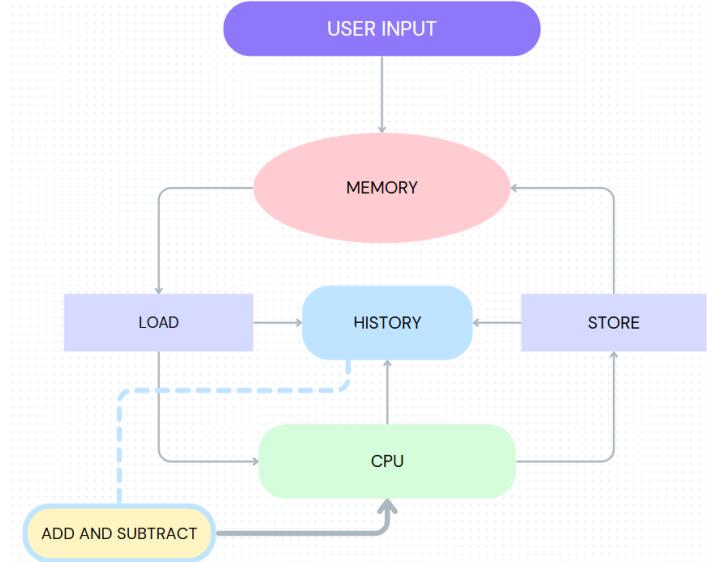
- Gradient background using LinearGradient
- Custom animated buttons using ElevatedButton.icon
- Responsive layout using LayoutBuilder
- Custom styled text fields for memory input

- Animated history list with ListView.builder
- Custom dropdowns for instruction selection

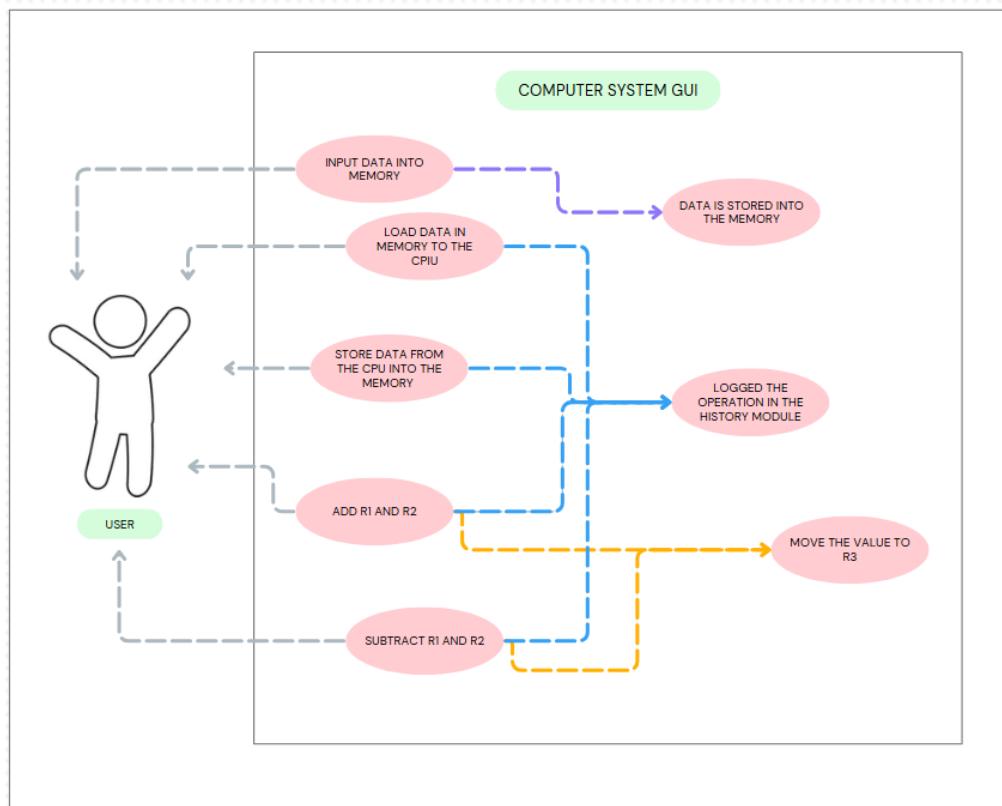
#### Performance Considerations:

- Efficient state management using setState
- Proper disposal of controllers in dispose method
- Optimized animations using TickerProviderStateMixin
- Memory-efficient list implementations

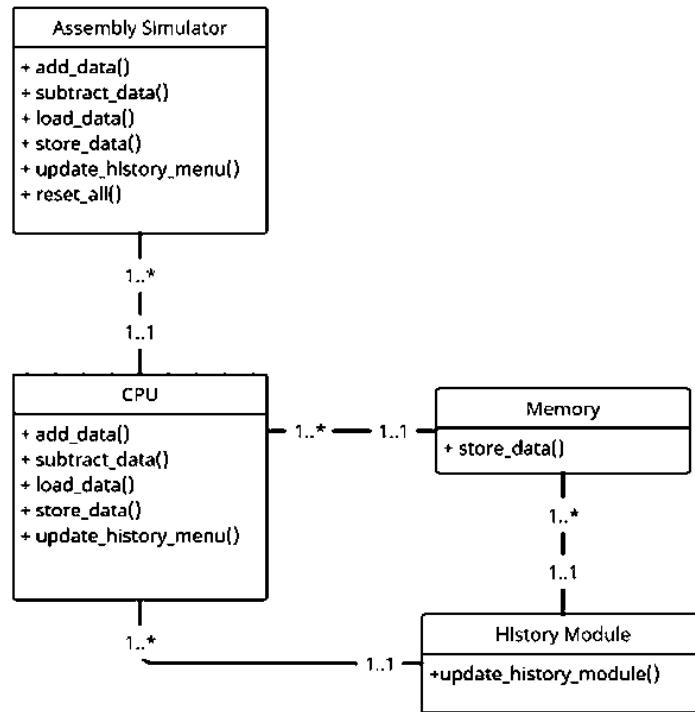
#### Conceptual Diagram



#### Use-Case Diagram



## Class Diagram



## Answers to Test Cases

After creating the simulator. Answer the following questions:

- Suppose the memory has the following contents:

A1	A2
2	5

```

MOV R1, A1
MOV R2, A2
ADD R1, R2
MOV R3, R1
MOV A4, R3
  
```

Simulate the instructions above then take a screenshot of the memory and the history module.

The screenshot shows the CPU Simulator interface with three main panels: CPU, Memory, and History.

- CPU Panel:** Shows registers R1, R2, and R3 with values 7, 5, and 7 respectively.
- Memory Panel:** Shows memory locations A1 through A10. A3 is highlighted with a pink bar, containing the value 7. Other locations are empty.
- Instructions Panel:** Contains two sections: LOAD and STORE. Under LOAD, From: A3 and To: R1 are selected. Under STORE, From: R3 and To: A3 are selected. Below these are buttons for Add (R1 + R2 → R3) and Sub (R1 - R2 → R3).
- History Panel:** Lists the following operations:
  - Load: A1(2) → R1(2)
  - Load: A2(5) → R2(5)
  - Add: R1 + R2 → (2) + (5) → R3(7)
  - Store: R3(7) → A3(7)
  - Load: A3(7) → R1(7)

The central logo reads "CPU SIMULATOR".

2. Suppose the memory has the following contents:

A1	A2	A3	A4	A5
5	4	3	2	1

Make the instructions that would reverse the order of values as follows:

A1	A2	A3	A4	A5
1	2	3	4	5

```

MOV R1, A1
MOV R2, A5
MOV A1, R2
MOV A5, R1
MOV R1, A2
MOV R2, A4
MOV A2, R2
MOV A4, R1

```

Simulate the instructions then take a screen shot of the memory and the history module.



3. Suppose the memory has the following contents:

A1	A3	A6	A7	A10
25	5	30	36	20

Instructions:

```

MOV R1, A1
MOV R2, A3
SUB R2, R1
MOV R3, R2
MOV A3, R3
MOV R1, A6
MOV R2, A10
ADD R1, R2
MOV R3, R1
MOV A10, R3

```

Simulate the instructions above then take a screen shot of the memory and the history module.

✿ Your Virtual CPU Workspace ✿

The screenshot displays a virtual CPU workspace interface. On the left, there are two sections: "CPU" and "Memory". The "CPU" section shows registers R1, R2, and R3 with values 30, 20, and 50 respectively. The "Memory" section shows memory locations A1 through A10 with various values assigned. In the center, there is a "Instructions" panel with tabs for "LOAD" and "STORE". Under "LOAD", "From: A10" is selected and "To: R2" is set. Under "STORE", "From: R3" is selected and "To: A10" is set. Below these tabs are two buttons: "+ Add (R1 + R2 → R3)" and "- Sub (R1 - R2 → R3)". On the right, there is a "History" panel listing the sequence of operations performed by the CPU.

Operation	Description
Load	A1(25) → R1(25)
Load	A3(5) → R2(5)
Store	R1(25) → A1(25)
Store	R2(5) → A2(5)
Load	A1(25) → R2(25)
Load	A2(5) → R1(5)
Sub	R1 - R2 → (5) - (25) → R3(-20)
Store	R3(-20) → A3(-20)
Load	A6(30) → R1(30)
Load	A10(20) → R2(20)
Add	R1 + R2 → (30) + (20) → R3(50)
Store	R3(50) → A10(50)

**CPU SIMULATOR**